

alkali-metal-ion conducting ceramic comprising alkali-metal-beta- or beta"-X₂O₃, where X comprises at least one of Al, or Ga.

~~33~~ 33. A process for forming ceramic composites of an oxygen-ion conducting ceramic and an alkali-metal-ion conducting ceramic as in Claim ~~42~~ wherein the precursor ceramic comprises Al₂O₃ and the precursor ceramic is converted into a continuous phase of alkali-metal-beta- or beta"-Al₂O₃.

~~34~~ 34. A process for forming ceramic composites of an oxygen-ion conducting ceramic and an alkali-metal-ion conducting ceramic as in Claim ~~42~~ wherein the precursor ceramic comprises Ga₂O₃ and the precursor ceramic is converted into a continuous phase alkali-metal-beta- or beta"-Ga₂O₃.

~~43~~ 43. A process for forming ceramic composites of an oxygen-ion conducting ceramic and an alkali-metal-ion conducting ceramic as in Claim ~~42~~ wherein the precursor ceramic comprises a mixture of alpha-Al₂O₃ and Ga₂O₃, and the precursor ceramic is converted into continuous matrix comprising a mixture alkali-metal-beta- or beta"-Al₂O₃ and alkali-metal-beta- or beta"-Ga₂O₃.

~~44~~ 44. A process for forming ceramic composites of an oxygen-ion conducting ceramic and an alkali-metal-ion conducting ceramic as in Claim ~~43~~ wherein the mixture of alkali-metal-beta- or beta"-Al₂O₃ and alkali-metal-beta- or beta"-Ga₂O₃ is a solution of alkali-metal-beta- or beta"-Al₂O₃ and alkali-metal-beta- or beta"-Ga₂O₃.

62. A process for forming ceramic composites of an oxygen-ion conducting ceramic and an alkali-metal-ion conducting ceramic as in Claim 42 wherein the composite is subjected to a temperature of at least about 800°C.

78. A process for forming ceramic composites of an oxygen-ion conducting ceramic and an alkali-metal-ion conducting ceramic as in Claim 42 wherein the alkali metal comprises at least one of lithium, sodium, potassium, rubidium, or cesium.

89. A process for forming ceramic composites of an oxygen-ion conducting ceramic and an alkali-metal-ion conducting ceramic as in Claim 42 wherein the alkali metal comprises at least one of sodium, or potassium.

96. A process for forming ceramic composites of an oxygen-ion conducting ceramic and an alkali-metal-ion conducting ceramic;
forming a shaped composite comprising a precursor ceramic of α - X_2O_3 and oxygen-ion conducting ceramic, such that a continuous matrix exists in the composite for both the precursor ceramic and the oxygen-ion conducting ceramic,
subjecting the composite in the presence of a stabilizer to a vapor containing metal oxide of an alkali metal at sufficient temperature and for sufficient time to convert precursor ceramic into a continuous phase of alkali-metal-ion conducting ceramic comprising β "- X_2O_3 , where X comprises at least one of Al, or Ga, the stabilizer inhibiting the transformation of the β "- X_2O_3 to β - X_2O_3 .

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~~51.~~ A process for forming ceramic composites of an oxygen-ion conducting ceramic and an alkali-metal-ion conducting ceramic as in Claim ~~50~~ wherein the stabilizer comprises at least one of MgO, Li₂O, or ZnO.

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~~52.~~ A process for forming ceramic composites of an oxygen-ion conducting ceramic and an alkali-metal-beta- or beta"-alumina comprising;
forming a shaped composite comprising alpha-alumina and oxygen-ion conducting ceramic, such that a continuous matrix exists in the composite for both the alpha alumina, and the oxygen-ion conducting ceramic,
subjecting the composite to a vapor containing metal oxide of an alkali metal at sufficient temperature and for sufficient time to convert alpha-alumina into a continuous phase of alkali-metal-beta-alumina or alkali-metal-beta"-alumina.

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~~53.~~ A process for forming ceramic composites of an oxygen-ion conducting ceramic and an alkali-metal-beta- or beta"-alumina as in Claim ~~52~~ wherein the composite is subjected to a temperature greater than about 800°C.

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~~54.~~ A process for forming ceramic composites of an oxygen-ion conducting ceramic and an alkali-metal-beta- or beta"-alumina as in Claim ~~52~~ wherein the composite is subjected to a temperature between about 1200°C and 1500°C.

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~~55.~~ A process for forming ceramic composites of an oxygen-ion conducting ceramic and an alkali-metal-beta- or beta"-alumina as in Claim ~~52~~ wherein the shaped composite of alpha-alumina and the oxygen-ion conductor is embedded in a powder that releases the vapor

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containing the alkali-metal oxide at the temperature to which the shaped composite of alpha-alumina and the oxygen-ion conductor is subjected.

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~~56.~~ A process for forming ceramic composites of an oxygen-ion conducting ceramic and an alkali-metal-beta- or beta"-alumina as in Claim ~~52~~ wherein the alkali metal comprises at least one of lithium, sodium, potassium, rubidium, or cesium.

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~~57.~~ A process for forming ceramic composites of an oxygen-ion conducting ceramic and an alkali-metal-beta- or beta"-alumina as in Claim ~~52~~ wherein the alkali metal comprise at least one of sodium, and potassium.

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~~58.~~ A process for forming ceramic composites of an oxygen-ion conducting ceramic and an alkali-metal-beta- or beta"-alumina as in Claim ~~52~~ wherein the alkali metal comprises sodium, the vapor comprises an oxide of sodium, and the alpha-alumina is converted to sodium beta- or beta"-alumina.

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~~59.~~ A process for forming ceramic composites of an oxygen-ion conducting ceramic and an alkali-metal-beta- or beta"-alumina as in Claim ~~52~~ wherein the alkali metal comprises potassium, the vapor comprises an oxide of potassium, and the beta-alumina is converted to potassium beta- or beta"-alumina.

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~~60.~~ A process for forming ceramic composites of an oxygen-ion conducting ceramic and an alkali-metal-beta- or beta"-alumina as in Claim ~~52~~ wherein the vapor also contains a

stabilizer to inhibit transformation of beta"-alumina to beta-alumina and the alpha-alumina is converted to alkali-metal-beta"-alumina.

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~~61.~~ A process for forming ceramic composites of an oxygen-ion conducting ceramic and an alkali-metal-beta- or beta"-alumina as in Claim ~~58~~ wherein the stabilizer comprises at least one of MgO, Li₂O, or ZnO.

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~~62.~~ A process for forming ceramic composites of an oxygen-ion conducting ceramic and an alkali-metal-beta- or beta"-alumina as in Claim ~~59~~ wherein the alkali metal comprises sodium, the alkali-metal oxide in the vapor comprises an oxide of sodium, and the alpha-alumina is converted to sodium beta"-alumina.

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~~63.~~ A process for forming ceramic composites of an oxygen-ion conducting ceramic and an alkali-metal-beta- or beta"-alumina as in Claim ~~60~~ wherein the shaped composite of alpha-alumina and the oxygen-ion conductor is embedded in a powder that releases the vapor containing the alkali-metal oxide and the stabilizer at the temperature to which the shaped composite of alpha-alumina and the oxygen-ion conductor is subjected.

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~~64.~~ A process for forming ceramic composites of an oxygen-ion conducting ceramic and an alkali-metal-beta- or beta"-alumina comprising;
forming a shaped composite comprising alpha-alumina and oxygen-ion conducting ceramic, such that a continuous matrix exists in the composite for both the alpha alumina, and the oxygen-ion conducting ceramic,
subjecting the composite in the presence of a stabilizer to a vapor containing metal oxide of an

alkali metal at sufficient temperature and for sufficient time to convert alpha-alumina into a continuous phase of alkali-metal-beta"-alumina, the stabilizer inhibiting the transformation of beta"-alumina to beta-alumina.

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~~65.~~ A process for forming ceramic composites of an oxygen-ion conducting ceramic and an alkali-metal-beta- or beta"-alumina as in Claim ~~34~~ wherein the stabilizer comprises at least one of MgO, Li₂O, or ZnO.

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~~66.~~ A process for forming ceramic composites of an oxygen-ion conducting ceramic and an alkali-metal-beta- or beta"-alumina as in Claim ~~32~~ wherein the oxygen-ion conductor comprises a ceramic comprising at least one of zirconia, ceria, hafnia, or thoria.

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~~67.~~ A process for forming ceramic composites of an oxygen-ion conducting ceramic and an alkali-metal-beta- or beta"-alumina as in Claim ~~32~~ wherein the oxygen-ion conductor comprises a ceramic comprising at least one of yttria stabilized zirconia, rare-earth-oxide-doped zirconia, scandia-doped zirconia, rare-earth doped ceria, alkaline-earth doped ceria, stabilized hafnia, or thoria.

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~~68.~~ A process for forming ceramic composites of an oxygen-ion conducting ceramic and an alkali-metal-beta- or beta"-gallate comprising;
forming a shaped composite comprising alpha-gallate and oxygen-ion conducting ceramic, such that a continuous matrix exists in the composite for both the alpha gallate, and the oxygen-ion conducting ceramic,
subjecting the composite to a vapor containing metal oxide of an alkali metal at sufficient

temperature and for sufficient time to convert alpha-gallate into a continuous phase of alkali-metal-beta- or beta"-gallate..

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A process for forming a ceramic composite of an oxygen-ion conducting ceramic and an alkali-metal-beta- or beta"-alumina or gallate comprising; exposing to an alkali-metal oxide containing vapor a composite comprising a continuous phase of precursor ceramic of at least one of alpha-alumina, or alpha gallium oxide and a continuous phase of oxygen-ion conducting ceramic, the exposing at a temperature sufficient to diffuse alkali metal ions through alkali-metal-beta- or beta"-phase converted from precursor ceramic and oxygen ions through the oxygen-ion conducting ceramic to a reaction front where precursor ceramic is converted from the alpha-phase to the alkali-metal-beta- or beta"-phase.

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A process for forming a ceramic composite comprising a continuous phase of oxygen-ion conducting ceramic and a continuous phase of at least one alkali-metal- beta"-alumina or alkali-metal- beta"-gallate, the process comprising; exposing in the presence of a stabilizer a composite to an alkali-metal oxide containing vapor, the composite comprising a continuous phase of precursor ceramic comprising at least one of alpha-alumina, or alpha gallium oxide and a continuous phase of oxygen-ion conducting ceramic, the exposing at a temperature sufficient to diffuse alkali metal ions through alkali-metal-beta- or beta"-phase converted from precursor ceramic and sufficient to diffuse oxygen ions through the oxygen-ion conducting ceramic to a reaction front where precursor ceramic is converted from the

alpha-phase to the alkali-metal-beta"-phase, the stabilizer inhibiting transformation of the alkali-metal-beta"-phase to the alkali-metal-beta-phase.

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~~31~~. A ceramic composite comprising a continuous phase of an alkali-metal-ion conductor and a continuous phase of a ceramic oxygen-ion conductor, the alkali-metal-ion conductor comprising at least one of alkali-metal-beta-alumina, alkali-metal-beta"-alumina, alkali-metal-beta-gallate, or alkali-metal-beta"-gallate.

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~~32~~. A ceramic composite as in Claim ³¹~~31~~ wherein the alkali-metal of the alkali-metal-ion conductor comprises at least one of lithium-, sodium-, potassium-, rubidium- or caesium.

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~~33~~. A ceramic composite as in Claim ³¹~~31~~ wherein the alkali-metal-ion conductor comprises at least one of sodium-beta"-alumina or potassium-beta"-alumina.

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~~34~~. A ceramic composite as in Claim ³¹~~31~~ wherein the alkali-metal-ion conductor comprises sodium-beta"-alumina.

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~~35~~. A ceramic composite as in Claim ³¹~~31~~ wherein the ceramic oxygen-ion conductor comprises a ceramic comprising at least one of zirconia, ceria, hafnia, or thoria.

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~~36~~. A ceramic composite comprising a continuous phase of at least one of alkali-metal-beta-alumina or alkali-metal-beta"-alumina and a continuous phase of a ceramic oxygen-ion conductor.

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~~77.~~ A ceramic composite as in Claim ³⁶~~76~~ wherein the alkali-metal-of the alkali-metal-beta-alumina or alkali-metal-beta"-alumina comprises lithium-, sodium-, potassium-, rubidium- or caesium.

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~~78.~~ A ceramic composite as in Claim ³⁶~~76~~ wherein the alkali metal of the alkali-metal-beta-alumina comprises at least one of sodium- or potassium.

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~~79.~~ A ceramic composite comprising a continuous phase of at least one of sodium-metal-beta-alumina or sodium-metal-beta"-alumina and a continuous phase of a ceramic oxygen-ion conductor.

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~~80.~~ A ceramic composite as in Claim ³⁶~~76~~ wherein the ceramic oxygen-ion conductor comprises a ceramic comprising at least one of zirconia, ceria, hafnia, or thoria.

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~~81.~~ A ceramic composite as in Claim ³⁶~~76~~ wherein the ceramic oxygen-ion conductor comprises a ceramic comprising at least one yttria stabilized zirconia, rare-earth-oxide-doped zirconia, and scandia-doped zirconia, rare-earth doped ceria and alkaline-earth doped ceria, stabilized hafnia, or thoria.

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~~82.~~ A ceramic composite comprising a continuous phase comprising alkali-metal-beta- or beta"-gallate and a continuous phase of a ceramic oxygen-ion conductor.

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~~83.~~ A ceramic composite comprising a continuous phase of a mixture of alkali-metal-beta- or beta"-alumina and of alkali-metal-beta- or beta"-gallate, and a continuous phase of a ceramic oxygen-ion conductor.